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ABSTRACT

Described are the use and purposes of the Biomedical Instrumentation Package (BIP) in science classrooms. Science activities are suggested and equipment use is described. A sample laboratory activity, which includes materials, procedure, and discussion, is provided. (SA)

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INTRODUCING

THE

BIP

(Biomedical Instrumentation Package)

Many important electronic functions in one instrument.

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THE BIOMEDICAL INTERDISCIPLINARY CURRICULUM PROJECT

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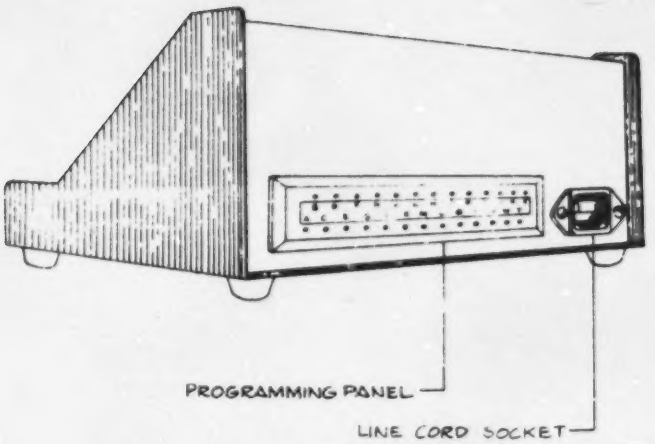
THE BIP



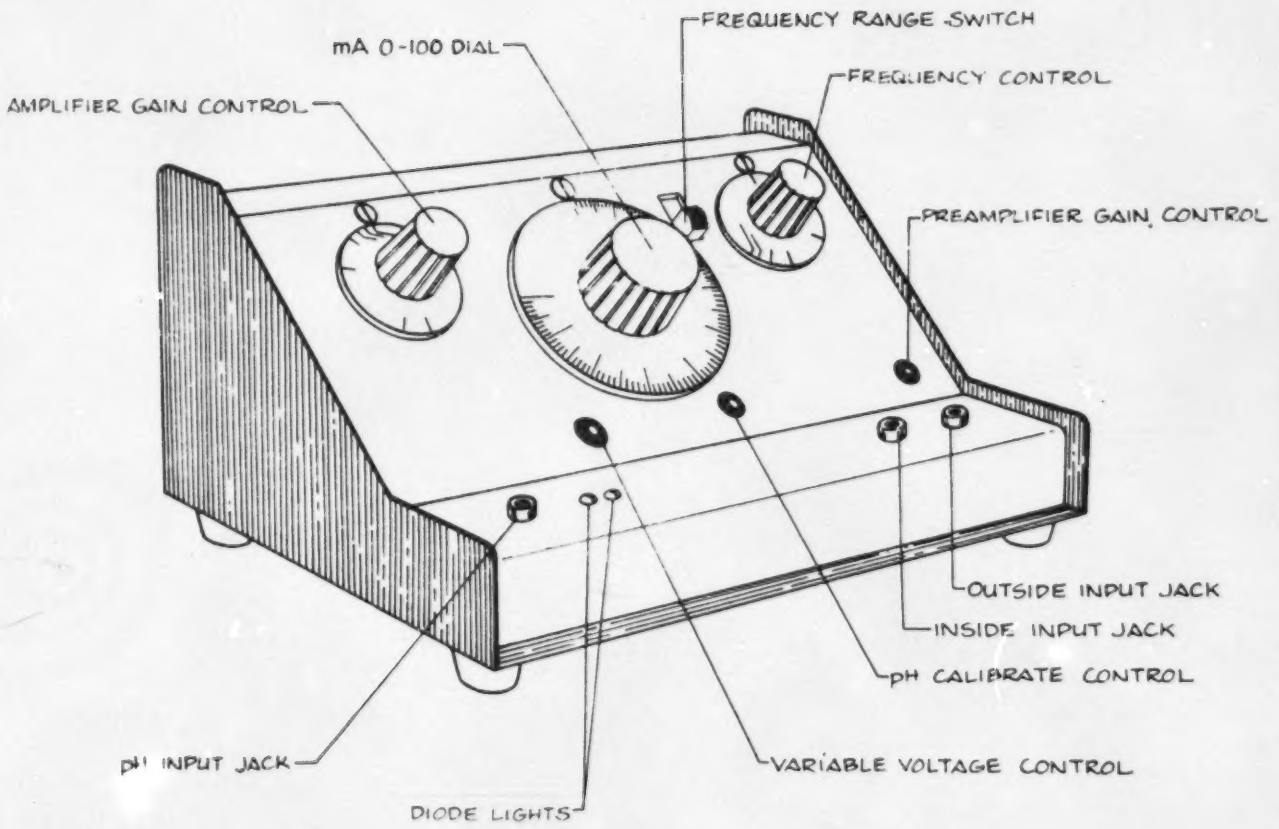


Figure 1

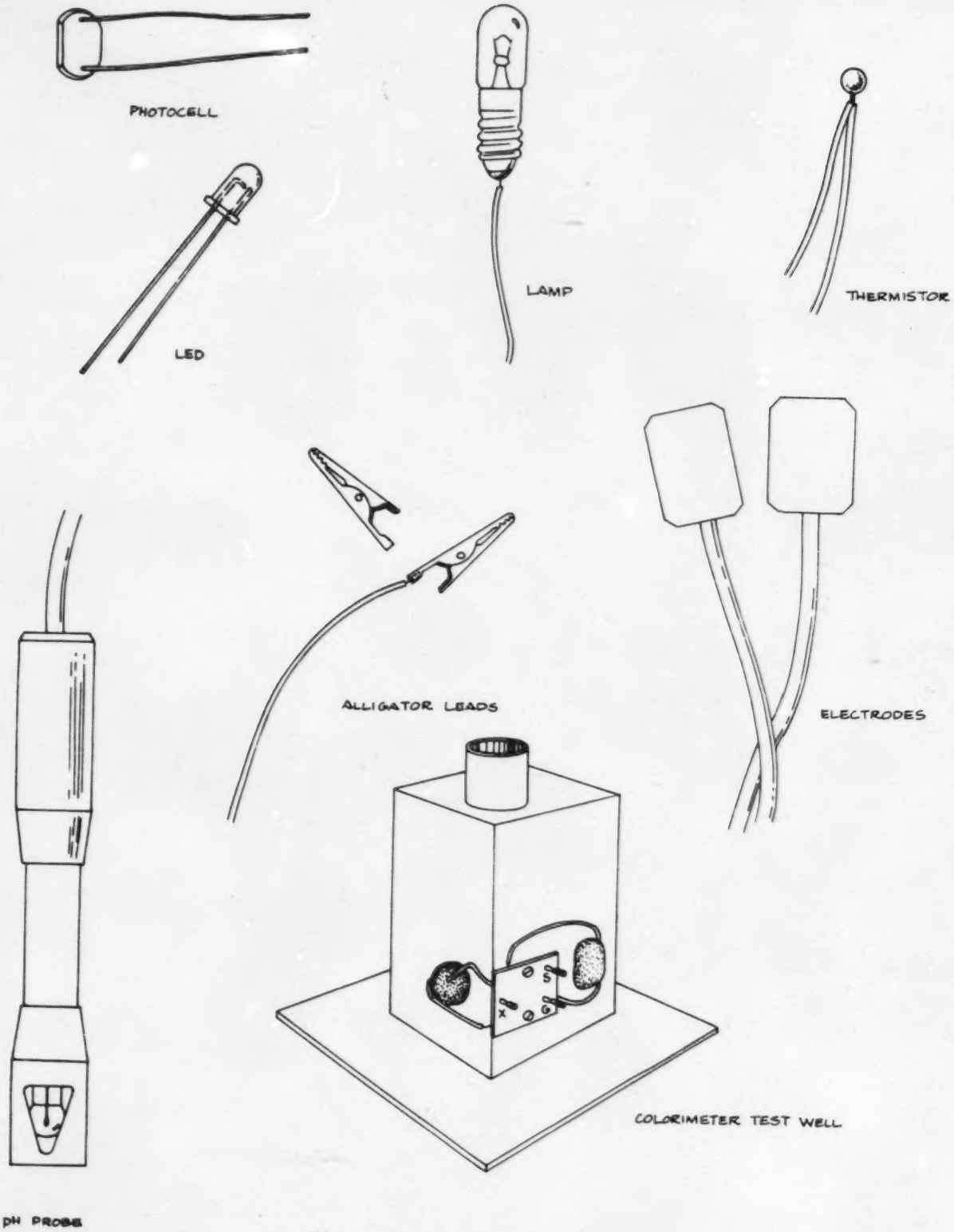


Figure 2: BIP Accessories

Note: Miscellaneous wire and resistors are not shown.

The Biomedical Instrumentation Package (BIP) is a student-programmable learning device that has been developed for a wide variety of science classroom activities. Its versatility and low cost enable students to perform hands-on laboratory activities not usually feasible at the high school level. The BIP was originally developed for the Biomedical Curriculum, written by the Biomedical Interdisciplinary Curriculum Project with the support of the National Science Foundation. The instrument can be used, however, to perform many other functions in the science classroom.

The BIP's versatility results from the many ways in which its six internal modules can be connected to external components to perform a desired function. Some of the classroom applications include:*

BIOLOGY AND PHYSIOLOGY

- demonstrating bioelectric phenomena such as the ECG and EEG (electrocardiogram and brain waves)
- measuring hearing acuity at different frequencies
- determining hemoglobin concentration of blood
- demonstrating the arteriolar pulse
- separating by electrophoresis the proteins in blood plasma
- determining the CO_2 concentration of expired air
- performing biofeedback experiments
- showing some physiological changes as a result of breath holding
- measuring electrical resistance of the skin at different body sites
- demonstrating the action potential of Nitella

CHEMISTRY

- measuring pH electronically (with a single pH electrode)
- performing electroplating
- showing the electrolysis of water
- demonstrating the reversibility of chemical reactions using colorimetry
- determining equilibrium constants by pH measurement

ECOLOGY

- measuring pollutants (NO_2) in automobile exhaust
- measuring noise level
- determining concentration of water pollutants by colorimetry

PHYSICS AND ELECTRONICS

- measuring electrical current
- measuring voltage
- measuring electrical resistance

*Note: A few of these applications will require additional components not included with the accessories.

- measuring light level
- producing sine waves in the audio frequency range
- measuring temperature with a thermistor

MATHEMATICS (in conjunction with the computer component)

- demonstrating symbolic logic with electrical circuits
- demonstrating binary counting with electrical circuits

NUTRITIONAL SCIENCE

- determining the protein concentration in foods
- determining the nitrite concentration in processed food
- determining the effect of diet changes on urine conposition
- determining the quality of a protein

HEALTH EDUCATION

- measuring the effect of noise on hearing acuity
- demonstrating the circulation changes that can result from tobacco smoking
- demonstrating voluntary modification of certain bodily functions (e.g., heart rate, skin temperature)
- measuring light levels for best reading conditions

The laboratory manual for the first year of the Biomedical Science course contains detailed procedures for the following BIP activities:*

COLORIMETRY: principles of (I-31)
measuring NO_2 concentrations in automobile exhaust (I-39)
measuring bilirubin content of gallstones (II-8)
analysis of protein concentration in foods (II-12)
determining glucose concentration (II-32)
determination of nitrite concentration in processed foods (II-37)
reversibility of chemical reactions and equilibrium constants (II-27)
determination of hemoglobin content of blood (III-10)
effect of diet on urine composition (III-20)
testing the artificial kidney model (III-23)

CONDUCTIVITY (of solutions) (I-24)

DENSITOMETRY: measuring the arteriolar pulse photoelectrically (III-5)

ELECTROCARDIOGRAPHY: visualizing the ECG waveform (III-8)

ELECTROLYSIS (of water) (I-35)

ELECTROPHORESIS (of amino acids and blood proteins) (III-12, 13)

*Note: Some activities will require the instructors manual to provide details of reagent preparations, etc.

ELECTROPLATING: (I-22)

OXIMETRY: experimenting with effects of breath holding (I-36)

pH: the use of a pH meter (I-30)
behavior of buffers (III-18)
applications of quadratic equations to pH problems (II-8)
effect of diet on urine composition (III-20)

TEMPERATURE: using a thermistor to measure skin temperatures (I-7)

TURBIDIMETRY: testing expired air for concentration of CO_2 (I-32)
determination of calcium concentration in urine
determination of bicarbonate concentration

The second-year laboratory manual includes procedures for BIP activities on:

- electrical safety
- audiometry and pure tones
- understanding electricity and Ohm's law
- noise pollution
- properties of light
- fundamentals of computer science (in conjunction with the computer component)
- biofeedback
- electromyography

Operation of the BIP is simple and straightforward. After the application or activity is selected, the student programs the BIP by making connections at the program panel with 24-gauge wire stripped of insulation at the tips (Figure 3).

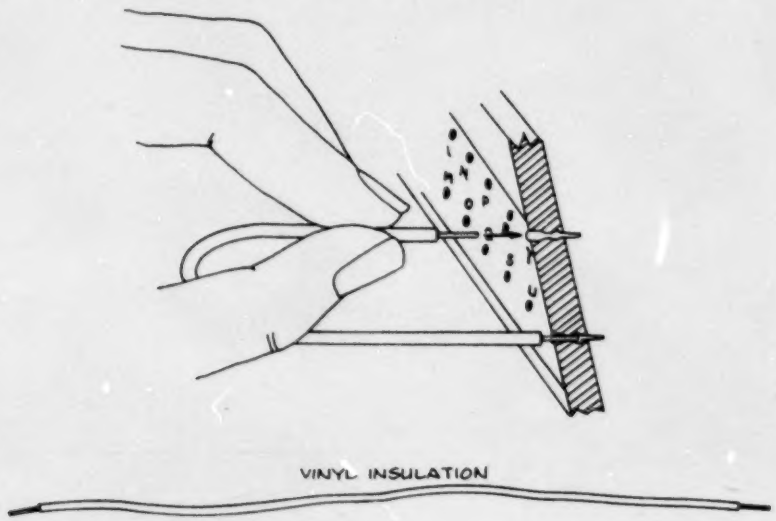


Figure 3

A simple program diagram is provided for every application.

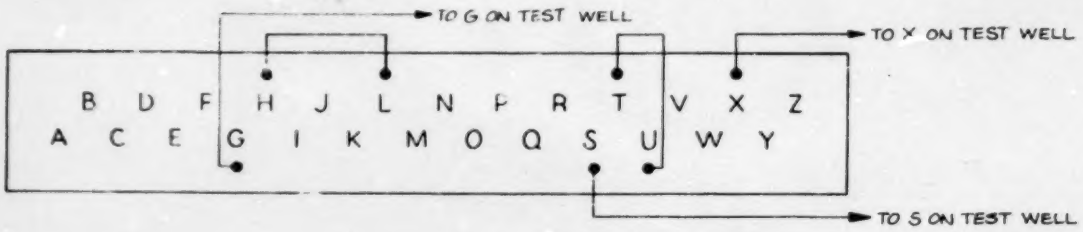


Figure 4

The program diagram shown in Figure 4 is for colorimetry. The short wires H to L and T to U interconnect internal modules to perform colorimetry (measurement of the intensity of light passing through a solution to determine concentration). Wires from G, S and X go to an external component, the test well, which receives the tube containing the colored solution.

For those interested in more technical details, a block diagram is shown in our BIP Manual which indicates, for each application, what modules have been connected and how they may relate to any external components.

The BIP contains six individual modules:

THE POWER SUPPLY

This supplies power to the other five modules. (To simplify programming, these modules have been interconnected internally.) In addition, this module supplies external power (for the colorimeter lamp, for example). Fixed voltages of +13 V, -13 V, and +5 V are available as well as an adjustable and stabilized +5 V to +7 V.

DIFFERENTIAL PREAMPLIFIER

This module amplifies the difference signal between two electrodes and is used primarily for bioelectric signals such as the ECG and brain waves. This module contains a differential amplifier which is needed to reject the unwanted 60 cycles per second AC that is radiated into the environment from power lines and fluorescent lamps.

pH PREAMPLIFIER

The pH probe produces extremely low-level currents. This module amplifies these currents to a level which can be measured.

SINE-WAVE GENERATOR

This module provides low-distortion sine waves, variable in frequency from 100 Hz to 10,000 Hz. Used with headphones, a typical application would be testing a person's hearing acuity for pure tones.

NULL-POINT CIRCUIT

All measurements made by the BIP utilize this module. The readout is on a 0-100 dial. It operates on the null principle with the indication being the point at which neither diode light is "on." Six different ranges from 0-1 mA to 0-300 mA allow the BIP to be used in many different applications.

POWER AMPLIFIER

This module amplifies a low-level audio signal (e.g., from the sine-wave generator) to a level sufficient to power a speaker or other electromechanical device.

Figure 3 provides a representation of the integrated modules of the BIP. It is not necessary to understand the electronic functioning of the modules to use them in many science applications. For those wanting such technical information, details can be found in the BIP Manual.

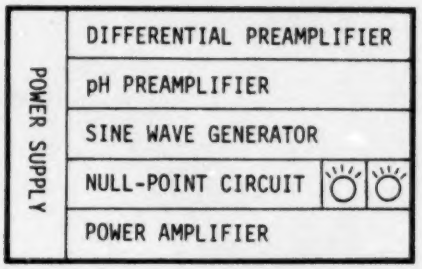


Figure 3: BIP Modules

[Taken from Biomedical Science Laboratory Manual, Unit III.]

LABORATORY ACTIVITY 10:

MEASURING THE HEMOGLOBIN CONCENTRATION OF BLOOD

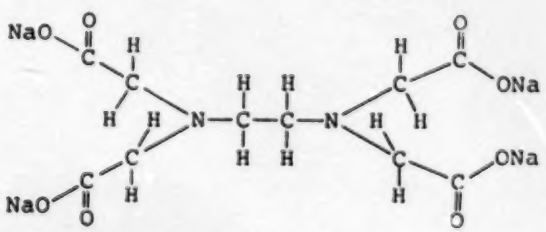
INTRODUCTION:

In Unit I on Respiration you learned that almost all of the oxygen carried in the blood is bound to the hemoglobin (abbreviated Hb) molecule. Since Hb carries O_2, the amount of oxygen the blood can transport depends on the amount of hemoglobin present.

A decrease in hemoglobin concentration, and the consequent reduction in oxygen-carrying capacity of the blood results in the condition known as anemia. A person is considered to be anemic if the blood hemoglobin concentration falls below 12 g Hb/100 ml blood for women and 14 g Hb/100 ml blood for men.

Several techniques are available to the medical lab technician for determining the hemoglobin concentration of a blood sample. One of the more accurate methods is the oxyhemoglobin method which you will be using in this activity. (Oxyhemoglobin is the name given to hemoglobin when it has oxygen atoms attached to it.) As blood is exposed to air, the hemoglobin molecules combine with O_2 to form oxyhemoglobin which is red. The concentration of oxyhemoglobin is then determined by colorimetry.

The directions call for mixing the blood with a solution of EDTA-Na_4 (ethylenediaminetetraacetic acid, tetrasodium salt). This salt (see formula on following page) has the ability to bind tightly to metal ions. It has two functions in the procedure: (1) to tie up metal ions that may be present in tap water (metal ions interfere with the analysis), and (2) to provide an alkaline environment which ensures that the hemoglobin is oxidized as fully as possible.



Tetrasodium salt of ethylenediaminetetraacetic acid (EDTA-Na_4)

MATERIALS:

tetrasodium salt of ethylenediamine-tetraacetic acid solution ($EDTA\text{-}Na_4$)

sterile blood lancet

alcohol cotton wipe packet

micropipet, 20-µl

pipet, 10-ml

2 cuvets, 16 x 125 mm, Pyrex

BIP colorimeter

glass-marking pencil

cotton or tissues

PROCEDURE:

1. Program the BIP for colorimetry and plug it in. (It should be allowed to warm up for at least 10 minutes before use.)

2. Label one cuvet "A" and the other "B".

3. Pipet 5 ± 0.1 ml of $EDTA\text{-}Na_4$ solution into each cuvet.

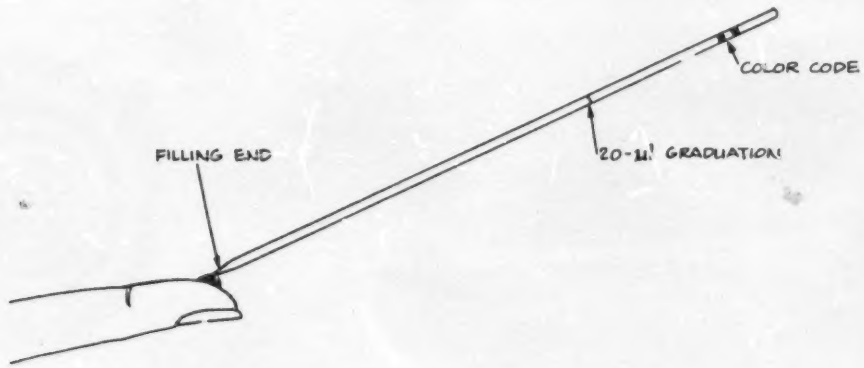
4. Puncture your finger as you did in Unit I. (The directions are repeated here for convenience.)

Choose someone to puncture your finger for you, unless you wish to do it yourself. (Note that most of the following instructions are for the person making the puncture.) First, examine--do not open--the package containing the sterile blood lancet. One end should read "open this end" or "peel to open." It is most important that you open that end, since it is the "handle" end. The opposite end is the blade, which you should not touch in order to keep it sterile.

The best finger to puncture is the one that gets the least use. This is usually the left ring finger (or the right ring finger for left-handed persons). Before the puncture is made, it is important to cleanse the skin. To do this, open the alcohol cotton wipe package. Then hold the finger with one hand and scrub its tip thoroughly with the alcohol wipe.

Open the blood lancet package. Make a quick, firm puncture with the lancet in the tip of the finger, using a rapid in-and-out motion. If blood does not flow immediately, quickly repeat the puncture. Dispose of the lancet as directed by your instructor. Used lancets are contaminated and can cause infection if reused by someone else.

5. Touch the filling end of your micropipet (see figure on the following page) to your puncture and allow the blood to rise up into the pipet until the meniscus is above the 20-µl graduation. (Note: If you are having trouble obtaining enough blood, place your thumb above the puncture wound and apply gentle pressure downwards towards the wound. If you still cannot get blood, repeat Step 4 using a fresh sterile lancet.)



6. Cover the color-coded opening of the pipet with your finger, and remove the pipet from the puncture.

7. Adjust the blood level in the pipet to the calibration line by touching the filling end of the micropipet to a wad of clean cotton or tissue until the meniscus is at the 20-µl mark.

8. Wipe off the outside of the pipet and discharge the blood into cuvet A. Gently blow air through the pipet to facilitate its emptying.

9. Rinse the pipet 3 to 4 times by carefully drawing the EDTA-Na_4 blood solution in cuvet A up into the pipet and gently blowing it out again each time. This is done to ensure a complete transfer of the blood to the EDTA solution.

10. Standardize the colorimeter at 100% transmittance using the EDTA-Na_4 blank (cuvet B).

11. Find and record the percentage transmittance for the cuvet containing your blood sample (cuvet A).

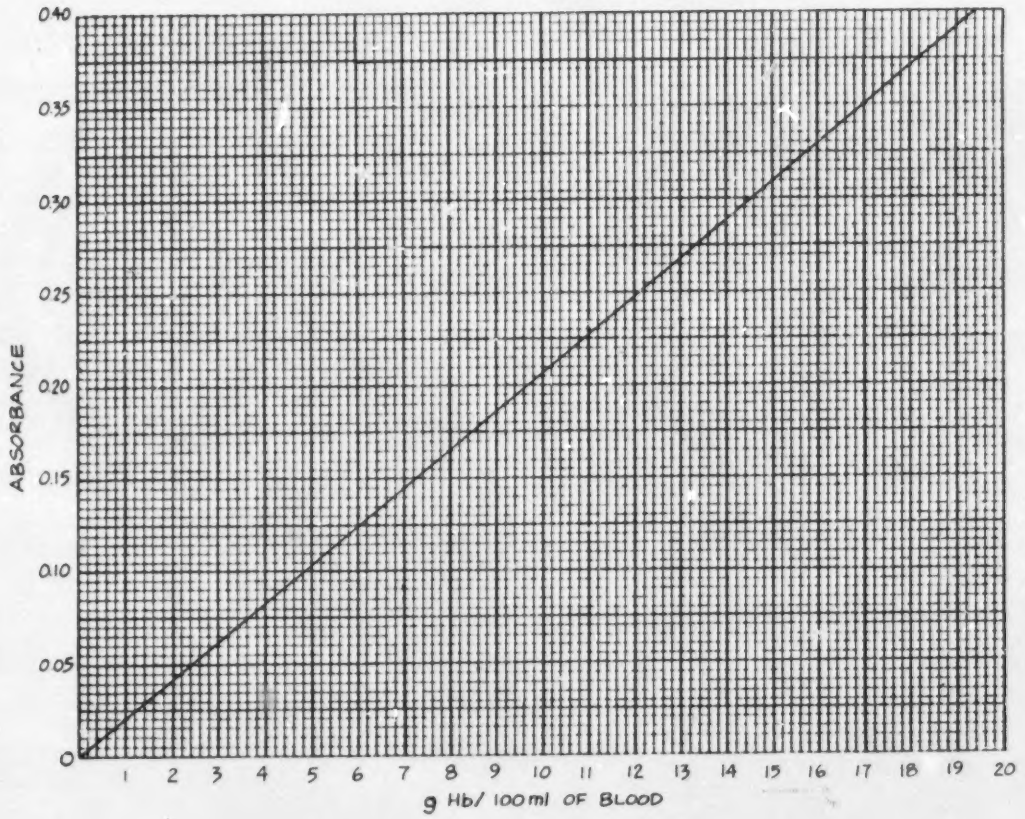
12. Determine the corresponding absorbance.

13. Use the standard graph (on the next page) to convert the absorbance of your blood sample into hemoglobin concentration in g Hb/100 ml of blood. Record the value.

DISCUSSION QUESTIONS:

1. How do your results compare with the values given for anemia in the introduction to the procedure?

2. Does there seem to be any consistent difference between the values for males and those for females?


0.40
0.35
0.30
0.25
0.20
0.15
0.10
0.05
0
ABSORBANCE
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20
g Hb/ 100ml OF BLOOD

[Taken from Biomedical Science Laboratory Manual, Unit III.]

LABORATORY ACTIVITY 8:

ELECTROCARDIOGRAPHY

INTRODUCTION

As the heart muscle beats, a current of electricity passes through the heart muscle and creates a characteristic electrical pattern. This electrical pattern can be recorded by connecting a person to a device which receives the electrical impulses from the person's heart, amplifies them, and produces a tracing on tape (Figure 1). This tracing is called an electrocardiogram (ECG).

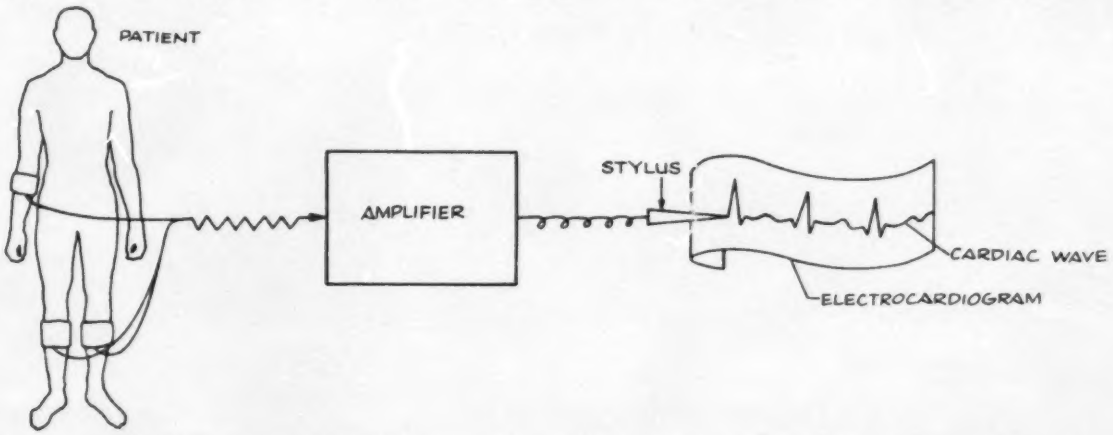


FIGURE 1: Schematic diagram of an electrocardiograph.

In this activity you will program the BIP to function as an electrocardiograph and observe your heart's electrical pattern.

MATERIALS:

- BIP
- electrode with unshielded cable (thin wire)
- 2 electrodes with shielded cable (thick wires with plugs)
- 18-KΩ resistor with two leads
- 3 elastic bandages or strips of 2" gauze, each 3 ft long
- roll of masking tape or fasteners for elastic bandages
- acetone
- cotton or cotton balls
- electrode paste

PROCEDURE:

1. Program the BIP as shown in Figure 2. (Additional connections are shown for use of an oscilloscope, in case one is available.)

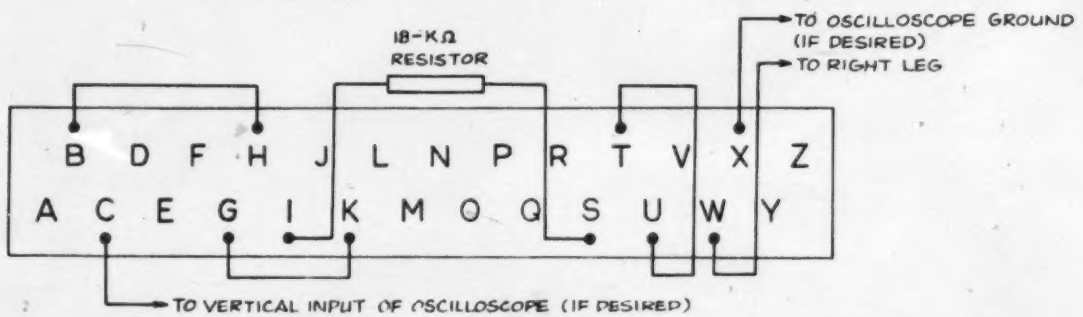

18-KΩ RESISTOR
TO OSCILLOSCOPE GROUND (IF DESIRED)
TO RIGHT LEG
B D F H J L N P R T V X Z
A C E G I K M O Q S U W Y
TO VERTICAL INPUT OF OSCILLOSCOPE (IF DESIRED)

FIGURE 2: Programming the BIP for electrocardiography.

2. Connect a student to the BIP. (Don't plug in the BIP until Step 9.) First, have the student sit on a chair. Then, using acetone (or soap and water), thoroughly clean an area on the parts of the body numbered 1, 2 and 3 in Figure 3. The cleaned areas should be somewhat larger than the size of the ECG electrodes. This is done to remove skin oils which could prevent good electrical contact. This is very important. Poor electrical contact between the electrodes and the body is one of the chief causes of failure of this activity.

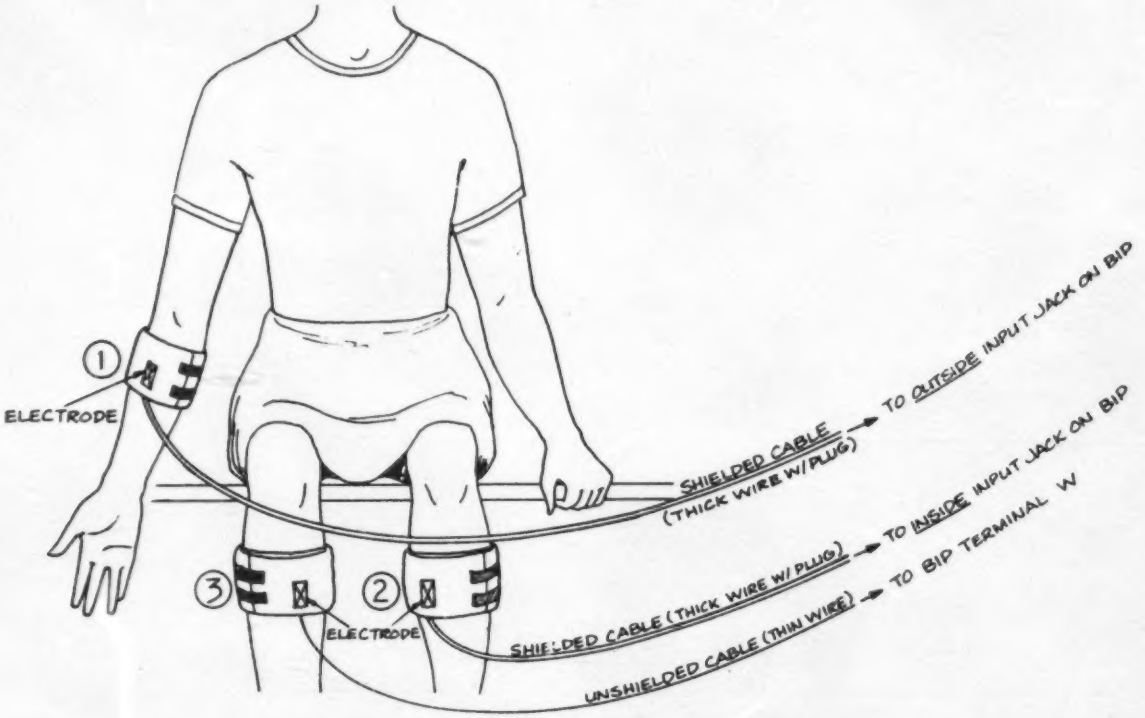


FIGURE 3: Electrocardiograph connections.

3. Smear electrode paste on one of the electrodes attached to a shielded cable. Bandage this electrode to body site #2 in the diagram. Be sure the electrode does not slip from the cleaned area during bandaging. Smear electrode paste on the other electrode attached to a shielded cable and bandage it to body site #1.

4. Repeat this procedure for the remaining electrode. (This electrode should have an unshielded cable.) Bandage the electrode to body site #3.

5. Observe the BIP and note the two input jacks in the bottom right hand corner of the front panel (Figure 4). Insert the electrode lead from the left leg into the inside input jack and the electrode lead from the right arm into the outside input jack (Figure 4). Be sure not to attach any of the electrode leads to the pH input jack (Figure 4, opposite).

6. Insert the electrode lead from the right leg (the one with the unshielded cable) into the W terminal on the BIP.

7. Turn the milliamp (mA) dial to 100 (Figure 4).

8. Set the slotted gain control about midway in its range (Figure 4).

9. Check all of your connections to be sure they are correct. Then plug in the BIP.

10. One diode light should be on continuously. We will call this the "negative" diode. The other diode is the "positive" diode. It should be off continuously. If it is not, the gain control setting is too high. Turn the slotted control (Figure 4) slowly in a counterclockwise direction until the positive diode remains off.

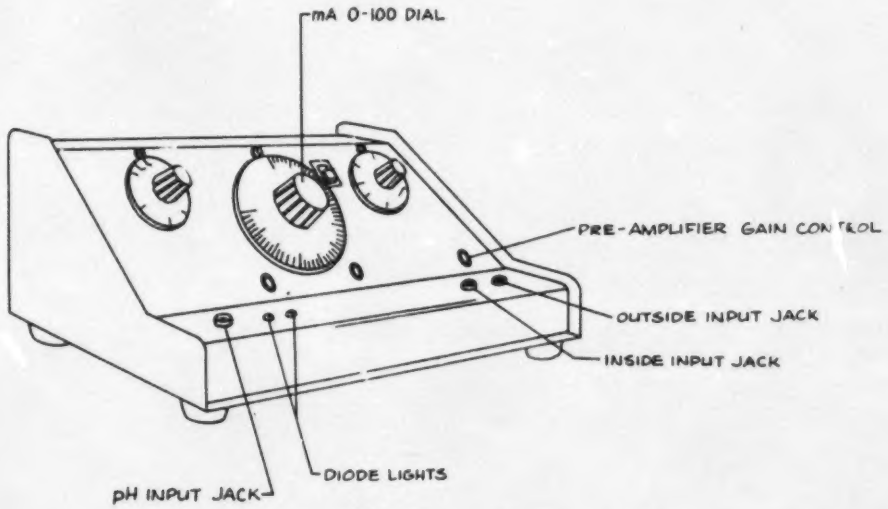


FIGURE 4: Front view of the BIP.

11. Slowly decrease the mA setting until the positive diode just flicks on and off (while the mA dial is held steady). Figures 5A and 5B show what has been happening. Reducing the mA reading is equivalent to lowering the height of the dashed line in the diagrams. The positive diode is on only when the cardiac wave form is above the dashed line. In Step 10 all of the wave form was below the mA setting, and the positive diode was off at all times. Figure 5B shows that, at the lower mA setting, the positive diode will come on briefly once each heartbeat, when the peak of the R wave occurs.

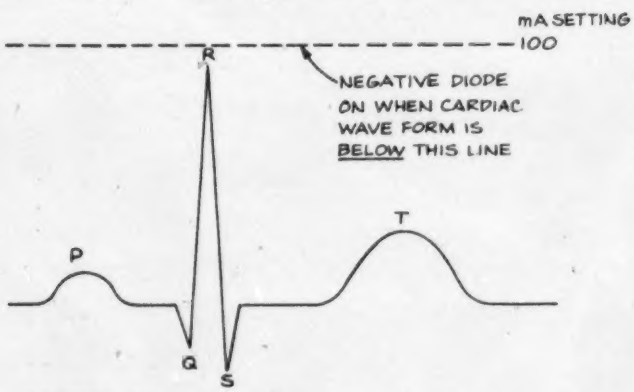


FIGURE 5A: Negative diode on continuously with mA setting of 100.

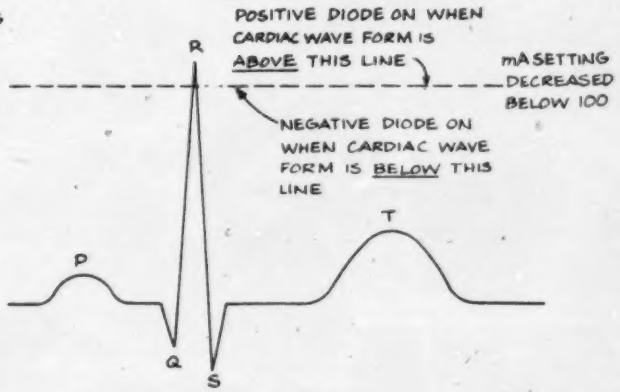

POSITIVE DIODE ON WHEN CARDIAC WAVE FORM IS ABOVE THIS LINE
R
mA SETTING DECREASED BELOW 100
NEGATIVE DIODE ON WHEN CARDIAC WAVE FORM IS BELOW THIS LINE
T
P
Q
S

FIGURE 5B: Positive diode on for each peak of R wave.

12. Figure 6 shows the effect of further decreases in the mA setting, as called for in the remainder of the procedure.

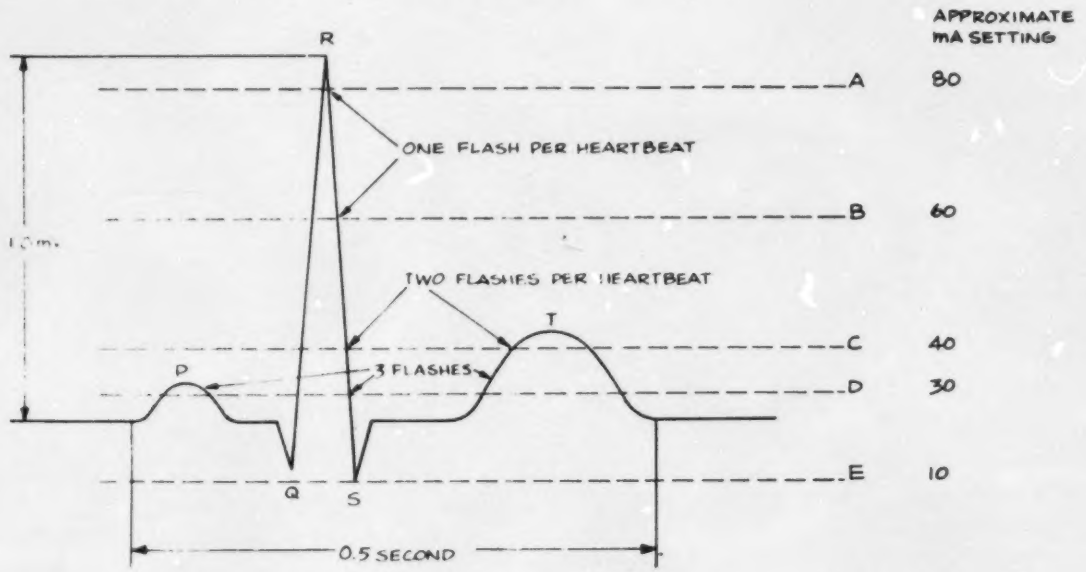


FIGURE 6: The relationship between mA setting and the ECG wave form.

Referring to Figure 6, when the mA dial is at "A" setting (as in Step 11) the positive diode will flash very briefly each time the R wave occurs. At setting "B" the flash will be longer because the R wave is wider. At setting "C" the R flash will be still longer and a second flash will also occur due to the T wave (Step 13). At setting D, a third flash, due to the P wave, will be seen (Step 14), followed by the R wave flash, and finally by a still longer T wave flash. The setting at D is tricky because if the dial is moved further toward setting "E" the diodes will begin to display signals having to do with the Q and S waves. The mA settings shown in Figure 6 are very approximate. Do not be concerned if your settings differ from the ones shown.

If you have difficulty in Steps 13 or 14, the gain control setting may be too low. If necessary, try turning the slotted control slightly in a clockwise direction.

13. Once again slowly decrease the mA setting until the positive diode flicks on and off twice during the same heartbeat. The positive diode is now displaying the peak of the T wave, as well as the R wave (Line C in Figure 6).

14. Again slowly decrease the mA setting until the positive diode flicks on and off three times in one heartbeat. The positive diode is now displaying the P wave peak, as well as the R and T waves (Line D in Figure 6). To make it easier to see the flashes of the positive diode, you might wish to cover the negative diode with masking tape or work in a darkened room.

DISCUSSION QUESTIONS:

1. Draw a typical electrocardiogram pattern and label the P, QRS, and T wave forms.

2. Match the wave with one or more cardiac-cycle events.

P	A. prepares ventricles for next activation wave
QRS	B. immediately precedes contraction of the atria
T	C. immediately precedes contraction of the ventricles

3. Distinguish between an electrocardiogram and an electrocardiograph.